RELATIONSHIPS BETWEEN SPEED, POWER, AND ENDURANCE IN YOUTH SOCCER PLAYERS

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ABSTRACT

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Soccer is a sport with an intermittent nature, and it includes both low- and high-intensity actions. In soccer, anaerobic and aerobic capacities play a key role in the performance and are therefore crucial determinants. Important actions that players need to be able to perform include sprints, jumps, tackles, change of directions, and accelerations. In order to test soccer performance, multiple field tests have been invented for their easy access and implementation during in-season and off-season. The purpose of the study was to examine the relationship between speed, power, and endurance in youth male and female soccer players and determine whether endurance performance can be predicted from sprinting and/or vertical jump ability.

A total of 154 youth soccer players from the highest competition level in Finland in the Under-15 and Under-17 age groups were included in the retrospective analysis for this study. Participants consisted of both males (n = 81) and females (n = 73). The experimental design for this study highlights the importance of the relationship between linear speed, power and endurance. Testing was done in Eerikkilä Sport Facilities and testing battery included countermovement jump, Yo-Yo intermittent endurance test level 2, linear speed (5m, 10m, 30m) and the repeated sprint ability tests. Adequate resting times were held between all the tests.

There were significant differences between males and females in all test variables ($p < 0.001$). In males, moderate correlations were observed between the YYIETL2 and the 30m ($r = –0.313$; $P = 0.004$), 5m ($r = –0.347$; $P = 0.002$), and 10m sprints ($r = –0.305$; $P = 0.006$). Moderate correlations were found between RSA_{Total} and the 30m ($r = 0.426$; $P < 0.001$) and 5m ($r = 0.360$; $P < 0.001$). Among females, moderate correlations were observed between the YYIETL2 and the 30m ($r = –0.394$; $P < 0.001$), 10m ($r = –0.325$; $P = 0.005$), and 5m sprints ($r = –0.307$; $P = 0.008$). Large correlations were observed between RSA_{Total} and the 10m ($r = 0.579$; $P < 0.001$) and 5m ($r = 0.501$; $P < 0.001$) sprints with a very large correlation between RSA_{Total} and the 30m sprint ($r = 0.719$; $P < 0.001$). Similarly, very large correlation was found between $RSA_{Average}$ and the 30m sprint ($r = 0.705$; $P < 0.001$).

This current study showed that sprint speed was moderately related to soccer-specific endurance performance in both female and male youth soccer players. Female players showed from large to very large correlations between sprint speed and RSA. This information could be used when the focus is to enhance RSA by increasing sprint speed. However, caution should be used when comparing the results with different populations as the test results may vary between players regarding sex and age group.

Keywords: youth players, sprint speed, yo-yo intermittent endurance test, countermovement jump

TIIVISTELMÄ

Kyöstilä, J. 2021. Nopeuden, voiman ja kestävyyden yhteydet nuorilla jalkapalloilijoilla. Liikuntatieteellinen tiedekunta, Jyväskylän yliopisto, valmennus- ja testausopin pro gradu -tutkielma, 50 s.

Jalkapallo on luonteeltaan jaksottaista urheilua, joka sisältää sekä matalan- että korkeanintensiteetin suorituksia. Jalkapallossa anaerobisilla ja aerobisilla ominaisuuksilla on keskeinen rooli suorituskyvyssä ja siksi ne ovat ratkaisevia tekijöitä. Tärkeitä toimintoja, joita pelaajien on kyettävä suorittamaan, ovat sprintit, hypyt, taklaukset, suunnan muutokset ja kiihdytykset. Jalkapallon suorituskyvyn testaamiseksi on keksitty useita kenttätestejä, jotka ovat helposti saatavilla ja toteutettavissa kauden aikana ja kauden ulkopuolella. Tutkimuksen tarkoituksena oli selvittää nopeuden, voiman ja kestävyyden yhteyksiä keskenään nuorilla mies- ja naisjalkapalloilijoilla sekä selvittää, voidaanko kestävyyssuorituskykyä ennustaa sprintti- ja/tai kevennyshypyn perusteella.

Tämän tutkimuksen aineisto koostui yhteensä 154 Suomen korkeimmasta kilpailutasosta olevasta nuorisojalkapalloilijasta, alle 15- ja alle 17-vuotiaiden ikäluokissa. Osallistujat koostuivat sekä miehistä (n = 81) että naisista (n = 73). Tämän tutkimuksen kokeellinen suunnittelu korostaa lineaarisen nopeuden, voiman ja kestävyyden välisen yhteyden merkitystä. Testaus tehtiin Eerikkilän liikuntatiloissa ja testausmenetelmät sisälsivät kevennyshypyn, Yo-Yo-jaksokestävyystestin taso 2, lineaarinopeuden (5m, 10m, 30m) ja toistettujen sprinttien testin. Kaikkien testien välillä pidettiin riittävät lepoajat.

Miesten ja naisten välillä oli merkittäviä eroja kaikissa testimuuttujissa ($p < 0,001$). Miehillä havaittiin kohtalainen korrelaatio YYIETL2:n ja 30 metrin ($r = -0,313$; $P = 0,004$), 5 metrin ($r = -0,347$; $P = 0,002$) ja 10 metrin sprintin ($r = -0,305$; $P = 0,0$) välillä. Kohtalainen korrelaatio havaittiin RSA_{Total} ja 30 metrin ($r = 0,426$; $P < 0,001$) ja 5 metrin ($r = 0,360$; $P < 0,001$) välillä. Naisilla havaittiin kohtalaista korrelaatiota YYIETL2:n ja 30 metrin ($r = -0,394$; $P < 0,001$), 10 metrin ($r = -0,325$; $P = 0,005$) ja 5 metrin sprintin ($r = -0,307$; $P = 0$) välillä. Suurta korrelaatiota havaittiin RSA_{Total} ja 10 metrin ($r = 0,579$; $P < 0,001$) ja 5 metrin ($r = 0,501$; $P < 0,001$) välillä, sekä RSA_{Total} ja 30 metrin sprintin välillä oli erittäin suuri korrelaatio ($r = 0,7019$; $P < 0,01$). Vastaavasti havaittiin erittäin suuri korrelaatio $RSA_{Average}$ ja 30 metrin sprintin välillä ($r = 0,705$; $P < 0,001$).

Tämä nykyinen tutkimus osoitti, että sprinttinopeus liittyy kohtalaisesti jalkapallokohtaiseen kestävyyteen sekä naisilla että miehillä nuorten jalkapalloilijoiden keskuudessa. Naispelaajilla oli havaittavissa suurta – erittäin suurta korrelaatiota sprintti nopeuden ja RSA:n välillä. Näitä tietoja voidaan käyttää, kun tavoitteena on kehittää RSA:ta lisäämällä sprinttinopeutta. Varovaisuutta tulee kuitenkin noudattaa verrattaessa tuloksia eri populaatioihin, koska testitulokset voivat vaihdella pelaajien välillä sukupuolen ja ikäryhmän mukaan.

Asiasanat: nuoret jalkapalloilijat, sprintti nopeus, jaksottainen yo-yo testi, kevennyshyppy

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1 INTRODUCTION

Soccer is a sport where aerobic endurance plays a key role in performance (Bangsbo, 1993). Also, factors like acceleration, sprinting velocity and jumping are very important. Therefore, it has been pointed out that higher aerobic power correlates with physical efforts during games (Reilly, 1997). It also allows players with higher aerobic power to keep up with the physical load and to be involved in various actions during the game (Helgerud et al., 2001). As soccer is heavily influenced by aerobic endurance and technical/tactical factors, training is also planned with this in mind. However, multiple studies have also pointed out that during games players need high anaerobic capacity as well (Sporis et al., 2008; Stølen et al., 2005; Haugen et al., 2013). During soccer, specific performance players need various explosive movements as they react to different external stimuli. Therefore, strength training is also a very important aspect of the whole training regime that soccer players do (Silva et al., 2015).

From previous studies, it has been proven that strength training with soccer-specific training will improve endurance capacity in soccer players (Silva et al., 2015). However, there is still debate on what kind of training design should be used as previous studies have shown different improvements on various tests (Silva et al., 2015). Strength training for elite athletes aims to improve players specific and athletic demands of their specific sport. Therefore, different strength training designs have been created to improve relevant demands of performance in a specific sport (Hoff & Helgerud, 2004).

An important aspect of intervention studies also is the time when the study is conducted. With some previous studies on soccer-specific endurance, large responsiveness to the training has been seen (Christensen et al., 2011; Krustrup et al., 2006a). These studies were conducted early pre-season and then the detraining of off-season could affect several physical attributes negatively so that the improvements seen from the studies seem to be very large in some of the attributes (Silva et al. 2015). Also, the challenges faced during implementations of physical training in a team sport is the schedule of the season, which is usually quite long and physically demanding, i.e., Multiple games and training per season (Walker & Hawking

2018). These challenges then force new training protocols to be developed that are time efficient and effective in youth players as they are very responsive to training (Silva et al., 2015, García-Ramos et al., 2018). With careful planning of the training, benefits for performance can be gained and over-reaching/overtraining can be avoided, and, also as the current literature in short durational strength training interventions for youth soccer players is still vague, more research is still needed (Silva et al., 2015, García-Ramos et al., 2018).

The main aim of this study is to find out how these two different strength training protocols (strength + plyometrics & strength + soccer-specific) will affect the endurance capacity in young soccer players and if those training outcomes translate to game performance in small-sided games.

2 PHYSICAL DEMANDS IN SOCCER

2.1 Game performance

The top elite soccer players cover 10-12km during a game and that includes every field player except goalkeepers who covered about 4km per game (Stølen et al., 2005). From previous studies, it has been reported that the midfield players run the most from any field players (Mohr et al., 2003; Ekblom 1986). There is also a difference between professional and semi-professional players in the time spent on high-intensity running and low intensity running (Mohr et al., 2003). These differences by Mohr et al. (2003) are shown in figure 1.

In soccer, during a game, there are multiple short sprints that players do, and these happen approximately every 90 seconds and only last for 2-4 seconds, and also various other explosive movements are needed during the game performance (Bangsbo et al., 1991; Helgerud et al., 2001). These movements include for example tackles, jumps, passing and shooting the ball (Helgerud et al., 2001). From the total distance, the high-speed sprints only constituted 1-11%, however, players' playing position affected greatly on the total distance and the number of sprints (Mohr et al. 2003). Game performance is also affected by how the team is playing from a tactical point of view and also how the opposing team is playing (Stølen et al., 2005). Despite that the sprints only constituted a low percentage of the total distance, newer studies have highlighted the importance of those high-speed movements during games (Di Salvo., et al 2010; Faude et al., 2012). In the study by Faude et al (2012), it was stated that straight-line sprinting was the most important action on goal scoring, which added the importance of high-speed action during the game performance.

Furthermore, the performance of soccer is not solely dependent upon the physical demands as it involves technical, tactical and psychological aspects as well (Stølen et al. 2005). However, there is no denying that the elite players need to have very good physical properties to compete at the highest level (Stølen et al., 2005; Silva et al., 2015). Adding the importance of high-speed movements, Barnes et al (2014) reported in their study, where they compared game performance from the English Premier League seasons 2006-07 and 2012-13, that the total distance covered in games remained approximately the same but the high-intensity running distance and sprinting distance increased by 30-35 %. Also in the same study, it was reported that the number of passes also increased between the years by 40%, which could be explained that the modern game is played more with the ball rather than without the ball (Barnes et al., 2014).

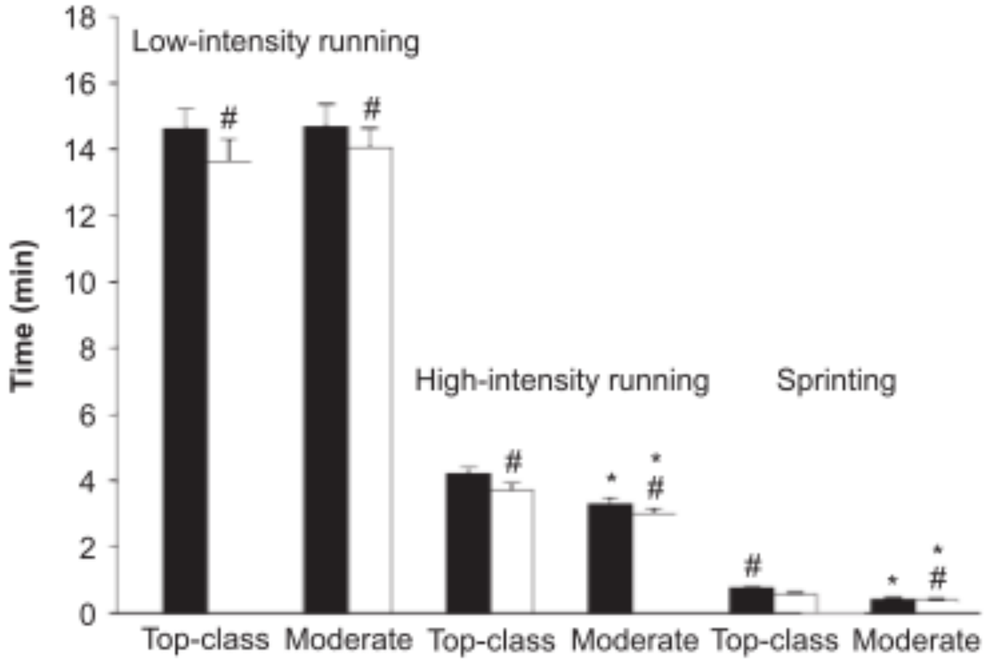

FIGURE 1. Time spent on different running intensities and sprinting between top-class players and moderate players. First (black) and the second half (white). # = significant difference between first and second half, * = significant difference between top-class and moderate players by Mohr et al. (2003).

2.2 Strength and power

Endurance is an important quality in soccer but equally important are strength and power too (Bangsbo et al., 1991; Stølen et al., 2005). Maximal strength is defined as the highest force that can be performed by the neuromuscular system, whereas power is defined as the ability to exert maximum force in a given time (Stølen et al., 2005). Strength training has been shown to improve sprinting performance and acceleration when done with heavy loads (85-100 % of 1RM) (Chelly et al., 2009). A significant relationship between 1RM and acceleration has been found and this has also been supported by increases in jump test results and longer sprints results (30m) (Wisløff et al., 2004). As soccer is dependable on multiple factors, strength training has shown to also be able to reduce injury risk (Silva et al., 2015). Furthermore, by increasing the activity of muscle contraction via the neuromuscular system it may enhance also important skills like the change of direction (COD) (Silva et al., 2015).

As the game performance in soccer is getting more athletic the importance of winning a sprint to the ball or winning a dual in the air is very important. Therefore, being able to produce muscle power in the short term is a necessary quality that is being focused on (Chelly et al., 2009). During the game performance in soccer to score a goal or stop a goal from being scored players should be able to be faster and more powerful than the opposing players (Chelly et al., 2009). Also, it was pointed out by Wallace & Norton (2013) that the game itself has changed over the years and they hypothesized that the game will continue to develop in the direction where faster and more powerful players will perform better as the game intensity continues to go higher. This is in line with reviews by Silva et al. (2015) and García-Ramos et al. (2018) where the amount of strength training protocols being developed for soccer is on the rise to help players deal with the physical demands of the modern game.

2.3 Endurance

The work intensity during a game performance in soccer is close to the lactate threshold (LT) or by the percent of maximal heart rate 80-90% (Reilly 1994). As mentioned before, the game performance includes high explosive movements which accumulate lactate, between these moments some low-intensity moments will help players to buffer lactate from the muscles (Helgerud et al., 2001). Players should be able to maintain the high intensity throughout the whole game but there have been studies showing that in the second half after 45min the players' distance covered is being reduced when compared to the results of the first half (Douglas 1993). A similar reduction was presented by Bangsbo et al (1991) in Danish players; the first half total distance covered was 5-9% greater than in the second half. Players with greater aerobic endurance may be able to avoid this reduction in the second half (Helgerud et al., 2001). In the study by Helgerud et al (2001) they showed that 8 weeks of endurance training improved game performance in young soccer players. They reported that the enhanced maximal oxygen uptake (VO2max) correlated with increases in total distance covered during games, amount of sprint increased and involvement in the game. Furthermore, the VO2max improved from 58.1 ± 4.5 ml/kg/min to 64.3 ± 3.9 ml/kg/min.

The total distance covered is related to the aerobic power and the player's ability to sustain that high utilisation of aerobic power (Hoff & Helgerud 2004). High endurance capacity has also been shown to be correlated with team success in elite soccer players (Apor 1988). Apor (1988) showed that the mean VO2max results were highest in the team that was highest in the league table in the Hungarian first division championship.

From the literature, it can be concluded that aerobic endurance is an important factor in soccer performance and that young players with higher aerobic endurance reported increases in total distance, number of sprints and total involvement in-game performance (Helgerud et al., 2001).

TABLE 1. VO_{2max} values (± SD) for soccer players by country and playing level (Modified from Stølen et al. 2005).

Study	Level/Country	n	VO_{2max} mL/kg/min
Apor (1998).	Professional/Hungary		66.6
Ekblom (1986).	Professional/Sweden		61.0
Helgerud et al. (2001).	Young professional/ Norway	9	64.3 ± 3.9
	Professional/ Norway	21	65.7 ± 5.22
Hoff et al. (2002).	Division 2/ Norway	8	60.3 ± 3.3
Impellizzeri et al. (2004).	Young/ Italy	19	57.4 ± 4.0
Wisløff et al. (1998).	Professional/ Norway	14	67.6 ± 4.0
	Professional/ Norway	15	59.9 ± 4.2

3 TRAINING IN SOCCER

3.1 Strength training

As the schedule of soccer players can be very hectic, time should be used as efficiently as possible. This applies to the training protocol as well. The main goal of strength training in soccer is to improve players' sport-specific and performance-related activities (Silva et al., 2015). In literature, the most commonly used strength training modes include traditional resistance training, plyometrics, weightlifting and sport-specific strength training (Silva et al., 2015; García-Ramos et al., 2018). The final aim of these modes is to enhance game-related performance, for example, linear sprinting, vertical jumping and change of direction (Silva et al., 2015). There is also the possibility to combine different exercise modes in training which allows optimal development both neurologically and morphologically (Ebben & Watts 1988).

In general, most studies that have researched strength training in soccer have used protocols that have 2-3 sessions per week and ranged between 4-12 weeks (Silva et al., 2015; García-Ramos et al., 2018). The number of different protocols used and loading schemes makes it very difficult to conclude the optimal protocols and this is widely accepted within elite soccer teams as the winning of matches usually overrules research interests (Silva et al., 2015).

In the study by Bogdanis et al. (2011) where they studied the effect of two different strength training protocols (Hypertrophic and maximal) for 6-weeks in young professional soccer players, they showed that the maximal strength training, 3 times per week, 4 sets of 5 reps (90% 1RM) of half-squat exercise significantly improved the 1RM strength for both groups. It is also important to note that the Yo-Yo intermittent endurance test results improved (m) (pre 1,684 ± 199, post 2,180 ± 210) and the effect size between pre and post was 0.89. Players' VO2max (ml·kg-1·min-1) improved also after the 6-weeks of maximal strength training (pre 51.3 ± 1.1, post 53.8 ± 1.4).

Similar findings have been shown by Wong et al. (2010) where professional soccer players performed 2 x/w for 8-weeks of concurrent strength training and high-intensity interval training. For strength exercise, they performed half-squat and bench press and the loads were determined from 6RM and loads were increased in 5kg increments. After the 8 weeks of training, the experimental group improved their 1RM half-squat (123.0 ± 1.5 kg to 148.0 ± 1.9 kg) and 1RM bench press increased from (65.3 ± 1.5 kg to 70.4 ± 1.1 kg). For soccer-specific endurance, they used the Yo-Yo intermittent recovery test 1 (YYIRT) and after the 8-weeks of concurrent training, the training group improved their YYIRT (1510 ± 75 m to 1808 ± 98 m).

These studies confirm that strength training will improve strength levels and more importantly it can also improve soccer-specific endurance. Whether strength training alone would be sufficient enough to enhance endurance in professional players remains a question but in a practical point of view, the order of endurance/strength training seems not to be so important (Silva et al., 2015).

3.2 Plyometric training

Combined training programmes could enhance performance-related tests better than just single orientated programmes on an elite level (Los Arcos et al., 2014). This could be one of the reasons why plyometric training is often used in addition to traditional strength training with soccer players (Silva et al., 2015). Plyometric training consists of jumping, hopping and bounding exercises that utilise the stretch-shortening cycle (Thomas et al., 2009). Plyometric exercises have been shown to improve muscle force and power production especially in fast production of the force (Hakkinen et al., 1985; Wagner & Kocak 1997).

In the study by Thomas et al. (2009), they studied the effects of two different plyometric programs in young semi-professional soccer players. Players were divided into drop jump (DJ) group and countermovement jump (CMJ) group and the training protocol lasted 6 weeks and training was done twice a week. The intensity of the training program was the same for both groups; they started with 80-foot contact at the start of the program and then progressed to 120-foot contacts in the end. Both groups improved their vertical jump height on the CMJ, however, both groups were unable to improve their sprinting time at 5,10,15 and 20m. Both groups also improved agility results after the 6-weeks, however, the agility testing was done with the 505-test and no external stimuli was reported, in case that, it is more a change of direction (COD) test rather than agility (Sheppard & Young 2006). Most importantly, plyometric training seems to improve many important qualities for soccer performance.

3.3 Endurance training

A soccer match is 90min long and players should be able to perform the whole period. The complexity of aerobic and anaerobic demands during the game put players in high physical demand. Furthermore, aerobic endurance is still an important factor for the whole performance during games and training (Hoff & Helgerud 2004). This has been proven as a significant correlation between VO2max and distance covered has been pointed out by Thomas & Reilly (1976). This has been supported by the finding by Helgerud et al. (2001). In soccer endurance training is mostly developed and maintained through competitive matches, friendly matches, technical/tactical training and small-sided games (Bangsbo et al., 2006). All of these are regularly used during team training and most of the training during in-season and pre-season consist of similar exercises (Silva et al., 2015).

Howard & Stavrianeas (2017) compared high-intensity interval training (HIIT) to steady endurance running in junior varsity soccer players for 10-weeks. They reported significant improvements for both groups in the Yo-Yo test 1, but there were no increases in both groups for the 40-yard sprint. They concluded that HIIT training-induced similar aerobic improvements to the traditional endurance running training. However, great improvements could be due to the fact of the player's fairly poor fitness level at the start of the training program.

As mentioned previously, small-sided games are commonly used in soccer for tactical drills but it has also potential to improve players' endurance capacity as well. In the review from Moran et al. (2019) they concluded that the small-sided games can improve endurance in young soccer players the same way as traditional endurance training. The traditional steady endurance training is an effective way to improve VO2max, but the intermittent nature of soccer performance rises problems (Harrison et al., 2015). Also, traditional endurance training does not challenge players during fatigued, as it has been shown that fatigue affects soccer performance negatively (Russell & Kingsley 2011).

In the study by Jastrzebski et al. (2014) they compared two different training programs in young soccer players. They divided the groups into small-sided games group and interval running group. The training program was 8-weeks long and both groups trained twice a week. They found that significant improvements in VO2max were only reported for the small-sided games group. Both groups showed relevant increases for HR. Furthermore, they concluded that the performance intensity was higher in the small-sided games group and they hypothesized that this was due to rivalry and game-like situations.

These results show that small-sided games can be a good alternative for improving endurance in young soccer players and it offers sport-specific training adaptations for the intermittent nature of the game (Moran et al., 2019).

4 ENDURANCE PERFORMANCE TESTING

4.1 Intermittent endurance

Soccer is by nature an intermittent sport as there are times when explosive movements are needed and times when players can go with low-intensity jogging/walking. For soccer performance, the ability to perform intermittent high-intensity bouts is a very important aspect (Mohr et al., 2003). Therefore, to test endurance in soccer players, sport-specific intermittent endurance tests have been developed. The Yo-Yo intermittent recovery tests 1 and 2 are the most commonly used tests to assess soccer players' endurance ability. These tests have been developed to assess endurance ability in field conditions. The Yo-Yo intermittent recovery test 1 (Yo-Yo IR1) and Yo-Yo intermittent recovery test 2 (Yo-Yo IR2) received popularity after the review by Bangsbo et al. (2008) and the tests were developed from the Legèr multistage fitness test. Both tests consist of two 20m shuttle runs and then 10s of active recovery by walking (5+5m). The turning signal after the first 20m and the speed is determined by a beep signal from an audio device (Bangsbo et al., 2008). Furthermore, the Yo-Yo IR2 uses more rapidly increased speed increments and might be suitable for more elite athletes rather than semi-professional as the physiological demands of the tests are higher than in the Yo-Yo IR1 (Figure 2.) (Krustrup et al., 2006a).

The Yo-Yo IR1 validity in relationship to match related performance has been demonstrated by studies showing a significant correlation between the Yo-Yo IR1 and total distance covered, and high-intensity distance covered (Krustrup & Bangsbo 2001; Castagna et al., 2009). The test has also been shown to correlate significantly with multiple variables of in-game performance such as high-intensity activity, total distance and high intensity running (Castagna et al., 2009). It has also been shown to correlate strongly with high-intensity activity in both young players and adults (Krustrup et al., 2003; Castagna et al., 2009). However, a higher relationship with the test and total distance covered was found in young soccer players when compared to adults (Krustrup et al., 2003; Castagna et al., 2009).

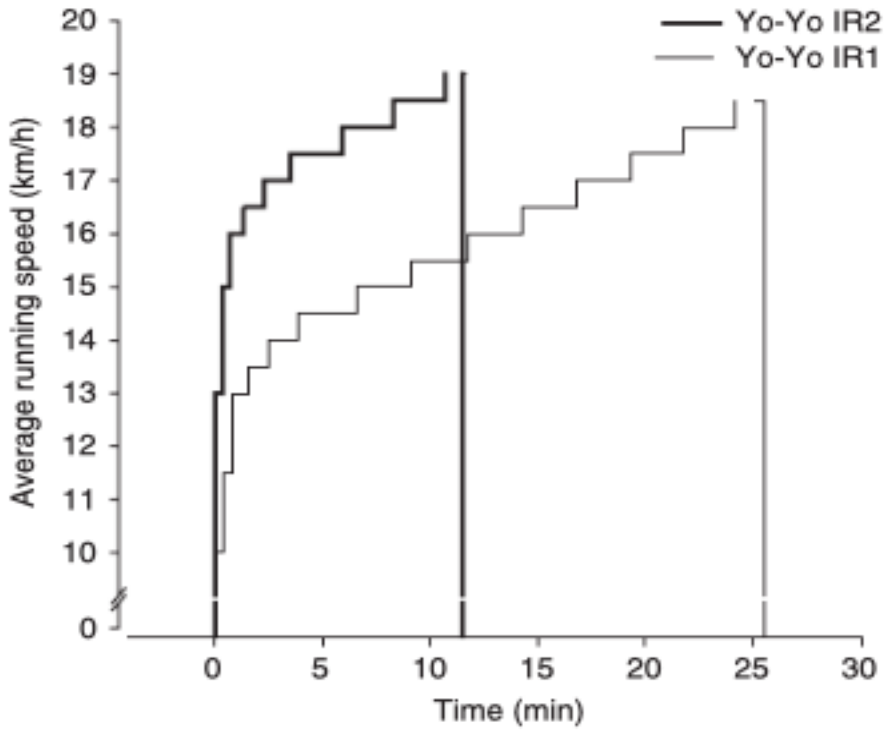

FIGURE 2. Schematic representation of the Yo-Yo IR1 and Yo-Yo IR2 tests by Krustrup et al. (2006a)

The Yo-Yo IR2 has shown to be accurate in following changes in the intermittent endurance performance in adult elite players (Krustrup et al., 2006a). As the speed increases of the Yo-Yo IR2 are increased at higher speed and it has higher physiological demands it may be suited for more anaerobic field test (Krustrup et al., 2006a). The Yo-Yo IR2 has been shown to have a relation with the VO2max in professional adult players (Krustrup et al., 2006a). Interestingly, when trained marathon runners' test results (Total distance) for Yo-Yo IR2 were compared to semi-professional soccer players, marathon runners reported significantly lower results than the soccer players, showing the importance of the specificity of intermittent tests and sport (Bangsbo et al., 2008).

It seems that the importance and use of both tests are in place for different levels of athletes and different ages (Bangsbo et al., 2008). The practical applications of both tests exist in literature and the nature of the tests should be focused on when choosing the right tests for different players and the performance-related measures that are of interest. The total distance obtained from the Yo-Yo IR1 and 2 can be used also to estimate theoretical VO2max, however, it has been pointed out that the estimations are not accurate as the Yo-Yo test are better at reflecting the intense intermittent performance (Bangsbo et al., 2008). The following equations are used for the theoretical estimation of VO2max:

Yo-Yo IR1:

VO2max (mL/min/kg) = IR1 distance (m) X 0.0084 + 36.4

Yo-Yo IR2:

VO2max (mL/min/kg) = IR2 distance (m) X 0.0136 + 45.3

By Bangsbo et al. (2008)

4.2 Repeated sprint ability

Repeated sprint ability (RSA) has been deemed as an important ability in competitive soccer (Rampinini et al., 2007). During soccer, match players perform approximately 200 high-intensity actions per game (Bangsbo et al., 2006). Therefore, players need to be able to cope with fatigue and the high physiological demands of those actions (Rampinini et al., 2009). It has been shown that RSA in professional soccer players correlates positively in-game performances such as the distance covered in high intensity (Rampinini et al., 2009). Also, it seems that players from the elite level are better at coping with the high-intensity actions during the game performance (Mohr et al., 2003).

One of the commonly used protocols for RSA testing was proposed by Rampinini et al. (2007) they used 6 x 40m (20m + 20m) shuttle sprints and each shuttle sprint was separated by 20s of passive recovery. Another protocol for RSA has been suggested by Krustrup et al., (2006b) and used by Chaouachi et al. (2010) on young professional soccer players which followed 7 x 30m and 25s of active recovery. In a study by Chaouachi et al. (2010), they stated that the protocol to be valid the sprint time of the first 30m could not be 5% slower than the best time over the 30m. They concluded that to assess players RSA profile a 5-6 x 30m could be used in the future (Chaouachi et al., 2010). Therefore, the proposed RSA protocol by Rampinini et al. (2007) seems to be the best option when testing RSA in soccer players.

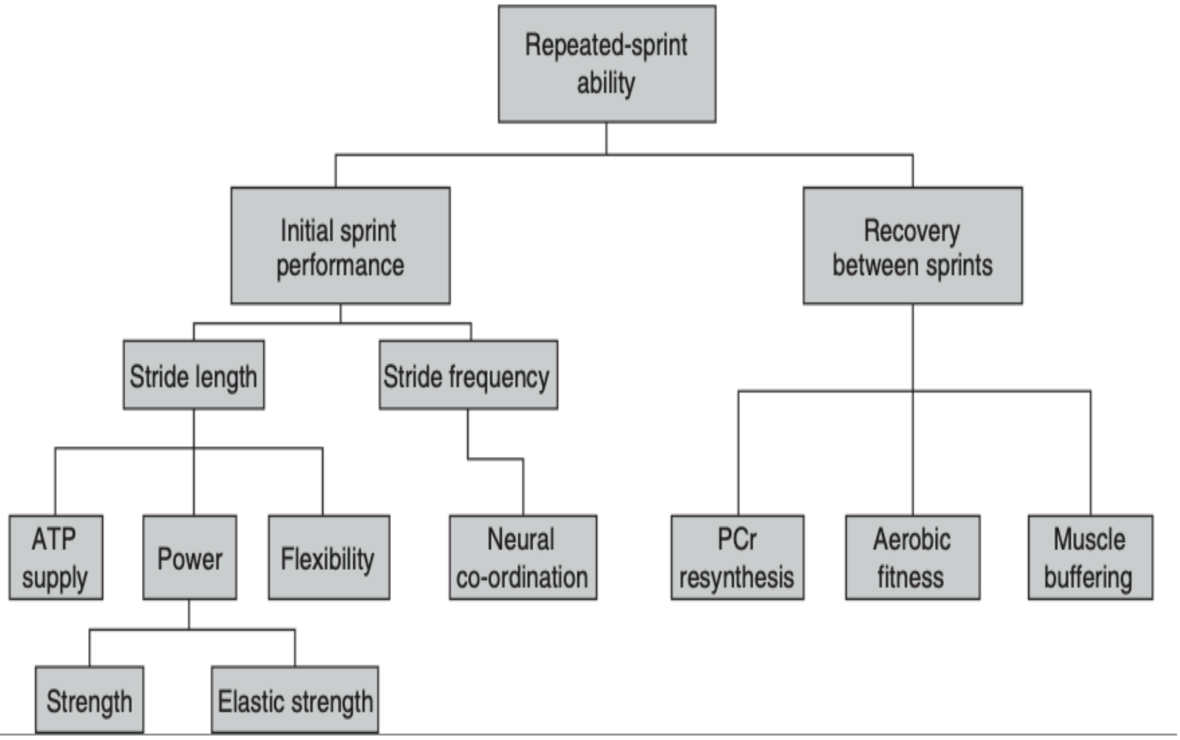

FIGURE 3. Important factors related to RSA by Bishop et al. (2011).

In the study by Rampinini et al. (2009), where they tested RSA on professional and amateur soccer players via the protocol from Rampinini et al. (2007). They measured times from best single sprint (RSA_{best}), meantime (RSA_{mean}), and percent decrement (RSA_{dec}). They reported that the professional players had better times on RSA_{best} and lower RSA_{dec} than the amateur players. They also reported that the RSA_{mean} and RSA_{dec} had a relationship to VO_{2max} in the professional players and moderate/low correlation. The physiological measures (La- $mmol·L^{-1}$, HR_{mean}, RPE, HCO3–mmol·L–1) obtained from HIT from their study did not correlate with the RSA test and they stated that VO_{2max} is not an important factor when the focus is on improving the RSA performance.

5 SMALL-SIDED GAMES

Small-sided games (SSG) are widely used in soccer as they allow coaches to interpret multiple focus areas that they want to develop such as skill, technical capabilities and endurance (Moran et al., 2019). SSG as a training model has also shown a beneficial effect on VO2max, jump, sprint, agility, RSA and intermittent endurance. The definition of small-sided games is that the pitch is smaller than in a competitive game and usually less than 11 versus 11 (Moran et al., 2019). Small-sided games are also practical as they use less space and the variables are easily modified like the number of players, game rules and pitch size. From these, the small-sided games can be used in various situations in at the same time improving soccer performance.

5.1 Small-sided games as training mode

Dellal et al. (2008) demonstrated that SSGs showed similar HR to intermittent running in professional soccer players. In the study, it was reported that during SSG players HR rise 80% HRmax. Dellal et al. (2012) also showed that in amateur soccer players the SSG training mode induced similar improvements in intermittent exercises after 6-week training. This is in line with the finding from the review by Moran et al. (2019). However, Moran et al. (2019) concluded in their review that the very elite level players might have a hard time getting to their physical limits in the SSG. It seems also that SSG can induce greater physical stress in the players which could improve aerobic fitness and cardiovascular function (Hammami et al., 2018).

Chaouachi et al. (2014) showed that the SSG training-induced large improvements in agility test with a ball when compared to the COD training program. In another study by Hill-Haas et al. (2009), they demonstrated that the SSG training mode was effective at improving the Yo-Yo IR1 performance (Figure 4.) but not VO2max in young professionals soccer players. Surprisingly neither the SSG training nor generic soccer training which included interval training, sprint training and RSA training did not improve RSA or sprinting. The mixed results of improvements may be due to different protocols used in studies as it has been pointed out those can affect whom SSG induces improvements in different skills and physical qualities (Hill-Haas et al., 2010).

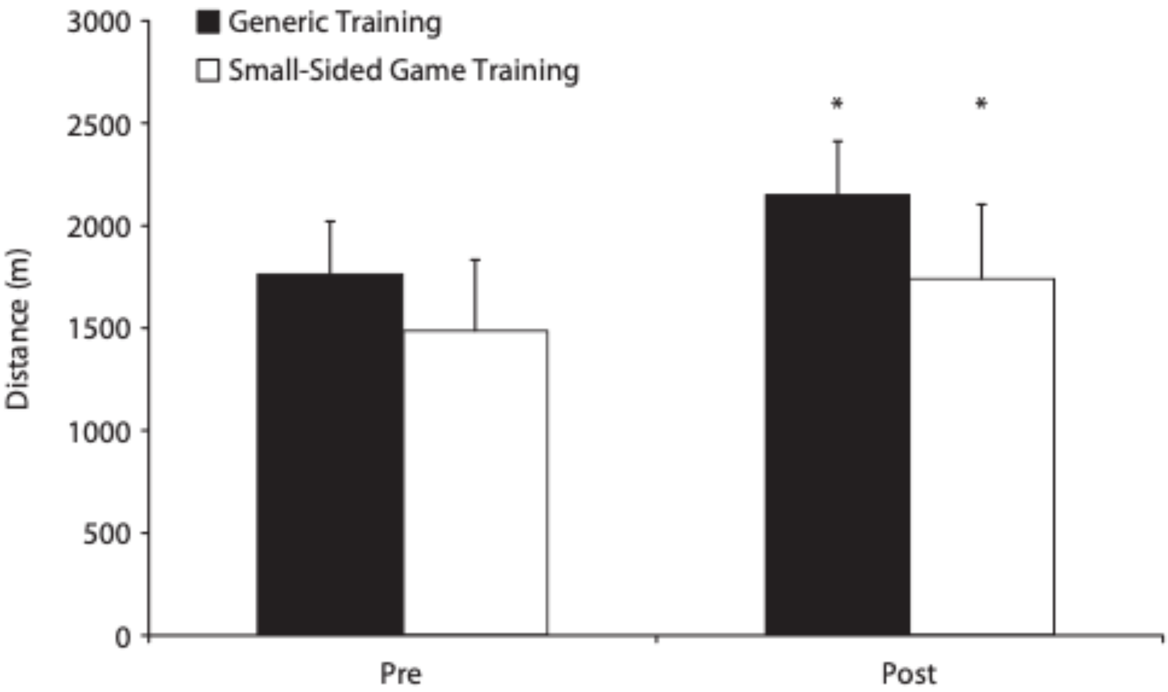

FIGURE 4. The changes in Yo-Yo IR1 (m) after 7-weeks of either generic or small-sided games training in Australian soccer players by Hill-Haas et al. (2009).

5.2 Variations of the SSG

SSG in training can be modified easily by changing the rules of the game or formatting the number of players is playing against each other for example 3 versus 3, 2 versus 2 or 3 versus 2 (Hill-Haas et al., 2010). Also in soccer, it is common to use periods where there is an upper hand on one of the teams for a certain amount by adding a player who plays with the team that has the ball. The intensity of the SSG can also be influenced by factors like pitch size, verbal encouragement and rules that are applied (Rampinini et al., 2007). In the study by Hill-Hass et al. (2010) they observed different SSG formats on physiological responses and time-motion characteristics (Total distance, mean speed, high intensity running, RPE, HR and BL) in young professional soccer players. They concluded that the main finding was that the rule changes in SSG appeared to have greater changes in the time-motion than on physiological responses. They also stated that 5-player and 6-player teams in SSG did not have any effect on acute responses in time-motion or physiological. They hypothesized that this could be due to bigger pitch size and that the involvement in the game decreased by players.

Rampinini et al. (2007) studied the effects of different SSG formats (3vs3, 4vs4, 5vs5, 6vs) on different pitch sizes (small, medium and large). They also wanted to observe how verbal encouragement would affect SSG exercise. They stated that the pitch size induced different physiological responses and that SSG on larger pitch size was more intense than the same drill on smaller pitch size. It was also found that the verbal encouragement during the SSG offered increases in intensity, and this could be an important aspect from a practical point of view for coaches. Also, importantly higher intensities were observed in 3vs3 when compared to 6vs6 as the players had more involvement with the ball.

5.3 Performance monitoring during SSG

Time-motion characteristics are widely monitored from SSG, and they are measured via the global positioning system (GPS). The intensity of the SSG is also commonly monitored by heart rate (HR), blood lactate (BL) and rate of perceived exertion (RPE). However, as the blood lactate measurements give valuable information about the fatigue during and after exercise the accuracy of measuring muscle lactate during soccer performance is poor (Krustrup et al., 2006b). Although the GPS is a reliable and valid method for monitoring various factors of external load there are also some limitations (Scott et al., 2016). The number of satellites connected to the GPS plays an important role in how accurately it can track the position of the user. Also, it has been found that indoors and tall buildings or stadiums can obstruct the signal (Scott et al., 2016). When moving at high speed the connection to the satellite from the GPS device can vary a lot and this can lead to errors (Scott et al., 2016). The most accurate GPS devices use the 10Hz and these have been found to be reliable and valid in multiple team sports performances and linear sports (Scott et al., 2016).

The portable GPS systems allow time-motion characteristics to be observed for example during competitive games and during training (e.g., small-sided games) (Hill-Haas et al., 2009b). Different speed zones can be adjusted from the devices so different periods of different intensity can be observed. From the total distance, it can be broken down into small sections, so the analysing of the whole performance is easier (Hill-Haas et al., 2009b). Also, caution should be used as the GPS devices used at over 20km/h show relatively poor reliability. The %HRmax is also widely observed during the small-sided games (Hill-Haas et al., 2009b; Rampinini et al., 2007).

To summarize this literature review. When planning strength training for professional soccer players multiple obstacles are faced as the schedule is very busy and the importance of winning matches usually overrules any kind of conditioning/strength training (Walker & Hawking 2018). Multiple different strength training protocols have been developed and it may be that protocols that have combined strength + sprint, plyometrics or sport-specific exercises offer improvements in the wider picture for important factors that are related to game performance in soccer (Los Arcos et al., 2014; Silva et al., 2015). However, the mixed findings of different protocols on physical assessments in soccer are still equivalent and whether combined or strength training alone can induce better improvements for example in endurance capacity (Bogdanis et al., 2011; Wong et al., 2010; Silva et al., 2015). Strength training protocols in soccer players have been useful for improving strength in young players and in adults as well and more importantly, strength training protocols have been shown to improve soccer-specific endurance as well (Silva et al., 2015).

6 SOCCER PERFORMANCE

It must be mentioned that because of COVID-19 the focus of this thesis changed as the original project had to be cancelled due to the restrictions in the city of Jyväskylä during early 2021. Therefore, the first part of this thesis remains as part of the old project and the literature review has a slightly different focus than the title implies. From chapter six and onwards this work covers the new topic of this thesis, which can be seen from the title.

Soccer is defined as a high-intensity sport with an intermittent nature as there are moments of high intensity and low-intensity actions (Bangsbo et al., 2006). High-intensity actions involve sprints, change of directions, tackles, jumps and accelerations while low-intensity actions involve jogging and walking (Stølen et al. 2005). Thus, both aerobic and anaerobic capacities play a key role in soccer performance and are therefore key determinates of performance (Bansgbo et al., 2008; Helgerud et al., 2001; Mujika et al., 2009). However, it should be noted that technical and tactical abilities contribute to the player performance as well (Bradley et al., 2013). These abilities can include playing style as well as shooting, ball handling, and passing ability (Bradley et al., 2013).

For soccer performance, the ability to perform intermittent high-intensity bouts is a very important aspect (Mohr et al., 2003; Stølen et al., 2005; Haugen et al., 2014). To test endurance in soccer players, sport-specific intermittent endurance tests have been developed which can be done in field conditions. The most common field test for endurance in soccer is the Yo-Yo intermittent test. The Yo-Yo intermittent test is a soccer-specific endurance test where participants need to run consecutive shuttle runs until exhaustion. After each shuttle run there is a recovery period that is either active or passive (Bangsbo et al., 2008). There are a few variations of the Yo-Yo intermittent test such as the Yo-Yo intermittent recovery test level 1 and 2 and the Yo-Yo intermittent endurance test level 1 and 2 (Krustrup & Bangsbo 2001; Castagna et al., 2009; Bradley et al., 2011; Bradley et al., 2014). Although the speed progression is similar between the Yo-Yo intermittent recovery test 1 (Yo-Yo IR1) and Yo-Yo IE2, the rest period between sprints is only 5s in the Yo-Yo IE2 compared to 10s in the Yo-Yo IR1 (Bangsbo et al., 2008). Regardless, performance on these tests has been shown to significantly correlate to the total distance run during match performance as well as the distance covered at high intensity during match performance (Krustrup & Bangsbo 2001; Castagna et al., 2009). The Yo-Yo intermittent endurance test level 2 (Yo-Yo IE2) has also been shown to correlate highly with running performance during matches for both men and women (Bradley et al., 2011; 2014). Papanikolaou et al (2019) showed that the reliability of Yo-Yo IE2 for total distance was nearly perfect in male soccer players, the intra-class correlation coefficient (ICC) was 0.870. Bradley et al (2014) reported that the Yo-Yo IE2 coefficients of variation (CV) in adult female players were 4.5 %. Similarly, the CV of Yo-Yo IE2 in youth male players was 3.9 % (Bradley et al., 2011). Then, for the Yo-Yo IR1 Krustrup et al (2003) reported a CV of 4.9 % in adult male players.

The vertical jumping ability has also been identified as a very important aspect of soccer performance as it is closely related to heading the ball (Stølen et al., 2005). Vertical jumping performance is usually evaluated through different types of jump tests such as the countermovement jump (CMJ), drop jump (DJ) and squat jump (SJ) (Castagna & Castellini 2013; Oliver et al., 2008). Vertical jump ability, specifically CMJ performance, correlates significantly with sprint performance in soccer players when sprinting over relatively short distances such as 5-20m (López-Segovia., et al 2011; McFarland et al., 2016). This may suggest that CMJ performance is an important indicator of sprinting ability, although the direction of causality for this relationship is not yet known (López-Segovia., et al 2011; McFarland et al., 2016). The reliability of CMJ for jump height has been reported to be high (ICC 0.90) (Behm & Kibele 2007). Also, the practicality of the test to detect changes accurately during the competitive season makes it popular among teams (Stølen et al., 2005).

The ability to perform repeated sprints in soccer is a relevant fitness prerequisite because players need to be able to perform multiple sprints when chasing the ball or opposing players (Stølen et al., 2005). Linear sprinting speed is one of the key components of repeated sprint ability (RSA) and therefore an important aspect of soccer performance (Bishop et al., 2011). RSA can be tested via several different tests (Krustrup et al., 2006b). In the literature, a common agreement has been achieved for the distance of the sprints (30m) but the number of sprints varies between protocols (Krustrup et al., 2006b; Reilly et al., 2000; Rampinini et al., 2009). A higher number of sprints (i.e., 5-7) is typically used for talent identification in soccer as the decrements of performance from the first to the final sprint can be easily identified (Reilly et al., 2000). Like the Yo-Yo intermittent tests, RSA-test performance is also influenced by both anaerobic and aerobic metabolism – both of which influence soccer-specific performance (Krustrup et al., 2006b). Similarly, RSA-tests have been shown to predict high intensity running and total sprint distance during a match performance in professional players (Rampinini et al., 2007). Baldi et al (2017) showed that the RSA mean time is also significantly correlated with the vertical jump. These findings imply that RSA should be considered when testing soccer players and planning their training to enhance this fitness prerequisite. Impellizzeri et al (2008) reported in their study that the short-term reliability for RSA mean time was (ICC 0.81), however, it should be noted that they used a 6 x 40m (20m + 20m) protocol with a 180-degree change of direction. Wragg et al (2000) showed in their study that for the 7 x 30m RSA protocol the reliability (%CV) was 1.8% across six trials for long-term reliability but reported also a small sample size (n = 7). In addition, they reported some practical difficulties as players only showed stability in the performance after three test trials (Wragg et al., 2000).

In summary, soccer is a sport that utilises both high intensity and low-intensity actions (Bangsbo et al., 2006). Therefore, the nature of soccer performance is intermittent. This has been highlighted when developing performance-related tests, which can be used to monitor training progress and highlight areas that might need more focus during training (Bangsbo et al., 2008; Helgerud et al., 2001; Krustrup et al., 2006b). Since the competitive season in soccer is long, there is no denying that players need multiple physical characteristics such as speed, power, and endurance to compete at the highest level (Bangsbo et al., 2006; Stølen et al., 2005). The aim of the present study is to examine the relationship between speed, power, and endurance in male and female soccer players and determine whether endurance performance can be predicted from sprinting and/or vertical jump ability. This information could then be used to see whether there are differences between boys and girls and to see whether there are important relationships between the tests, which could further inform the planning of training regimens for youth soccer players.

7 RESEARCH QUESTIONS AND HYPOTHESES

7.1 Purpose

While the direct validity between performance-related tests and game performance is a very important aspect, it is also an important aspect to evaluate how these performance-related tests correlate with each other and also to see whether performance can be predicted through a certain test. Interestingly, sex and age can play a role in how soccer players relationship between performance tests differs and also how accurately performance can be predicted from tests. Different testing protocols in most used field tests in soccer performance makes a comparison between studies hard. However, as the studies considering the relationship between field tests are rare, therefore it is important to evaluate these relationships between tests. Therefore, the purpose of this study was to investigate the relationship between speed and power on endurance capacity in youth soccer players and also to see whether soccer-specific endurance capacity can be predicted from speed and power performance.

7.2 Research questions and hypotheses

Question 1. Does speed, power and endurance differ between males and females?

Hypothesis: yes

It has been shown that, even if the relative physiological loads are similar between sexes in-game performance, female players have lower physical capacity than males when tested in soccer performance-related field tests, therefore males will outperform females in all measures (Stølen et al., 2005; Mujika et al., 2009).

Question 2. Is there a relationship between sprint speed and soccer-specific endurance capacity?

Hypothesis: yes

Endurance performance has been shown to have a strong correlation with speed in longer distances (40m), but not shorter distances (15m) (Gibson et al., 2013). Further, Castagna et al (2009) showed that Yo-Yo test performance correlated strongly with high intensity actions ($r = 0.77$, $p < 0.0001$) during a match and with high intensity running (13.0 to 18.0 $km \cdot h^{-1}$), ($r = 0.71$, $p = 0.0003$).

Question 3. Is there a relationship between lower limb power and soccer-specific endurance capacity?

Hypothesis: no

In adult male players, Rampinini et al (2007) showed that the vertical jump performance did not correlate significantly with total distance during a match performance. In young female players, Shalfawi et al (2014) showed similar findings – CMJ did not significantly correlate with intermittent endurance test performance. The majority of the literature shows that vertical countermovement jump score and performance in intermittent endurance tests show no significant correlation.

8 METHODS

8.1 Study design

A retrospective analysis was carried out on Finnish youth soccer players (*n* = 154) who performed field testing at Eerikkilä Sports Facilities in Eerikkilä, Finland during the competitive season. The testing battery included tests with and without the ball to fully evaluate each player's soccer-specific performance. The experimental design for this study highlights the importance of the relationship between linear speed, power and endurance. This study was conducted according to the Declaration of Helsinki and was approved by the ethics committee of the University of Jyväskylä.

8.2 Participants

A total of 154 youth soccer players from the highest competition level in Finland in the Under-15 and Under-17 age groups were included in the analysis. Participants consisted of both males (*n* = 81) and females (*n* = 73) and represented different teams across Finland. Anthropometric characteristics for all participants can be seen in table 1. All participants were informed of how the test results could be used for further research. Written consent for participating in the study was acquired from the guardians as the participants were under the age of 18.

TABLE 1. Anthropometric characteristics (Mean ± SD)

Sex	Age Group	Age (Years)	Weight (kg)	Height (cm)
Female	U15 (n=28)	15.4 ± 0.3	58.4 ± 7.7	168.1 ± 5.4
Female	U17 (n=45)	16.9 ± 0.6	62.7 ± 5.6	167.8 ± 5.3
Male	U15 (n=26)	15.6 ± 0.2	64.2 ± 5.9	177 ± 5.4
Male	U17 (n=55)	17.0 ± 0.6	73.4 ± 8.2	180.2 ± 6.3

8.3 Testing procedures

The participants visited the Eerikkilä Sports Facilities for two consecutive days. For this analysis, results from the countermovement jump, Yo-Yo intermittent endurance test level 2, linear speed (5m, 10m, 30m) and the repeated sprint ability tests were used. Adequate resting times were held between all the tests. Players were familiar with the testing procedures as all tests were included in their yearly follow up. All testing procedures were conducted after a standardized warm-up protocol.

8.3.1 Yo-Yo intermittent endurance test level 2

The layout for the Yo-Yo IE2 test is presented in figure 6. Testing was conducted on an artificial turf field. Participants performed several 20m shuttle runs, each followed by 5s (2,5+2,5m) of active recovery by walking. Participants began at the second cone and started by running towards the third cone after a beep signal from an audio device. After reaching the second cone, a second beep signal occurred indicating when to run back to the starting point. Over the course of the test, the duration between beeps decreased such that participants were required to adjust their speed as the test proceeded. The test ended if the participant failed to reach the lines between cones before the beep signal on two consecutive tries. Results were presented as total distance covered (m), excluding the active recovery portion (Bangsbo et al., 2008; Bradley et al., 2012).

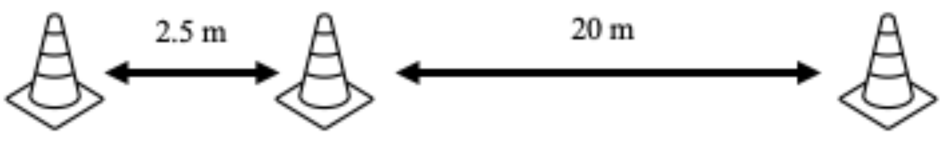

FIGURE 6. Schematic presentation of the Yo-Yo IE2 test.

8.3.2 Repeated sprint ability

The RSA protocol used in this study followed the pattern of 7 x 30m (Bangsbo, 1994.; Figure 7**).** The starting line was placed 0.7m from the first timing gates and participants were instructed not to sway back-and-forth at the starting line. Timing gates were placed at the first cone and last cone. Participants were instructed to sprint maximally from the first cone, around the three middle cones and finish through the final cone**.** After each sprint, participants had a 25s active recovery jog back to the starting line. Three seconds before the end of each recovery period, the subjects were told to get ready for the next sprint. There were two scores measured from the test, which were the average of all 7 sprints ($RSA_{average}$) and the total time of all 7 sprints (RSA_{total}). Sprint times were measured with SpinTest^{TM} (Spin Test Oy, Tallinn, Estonia) timing gates.

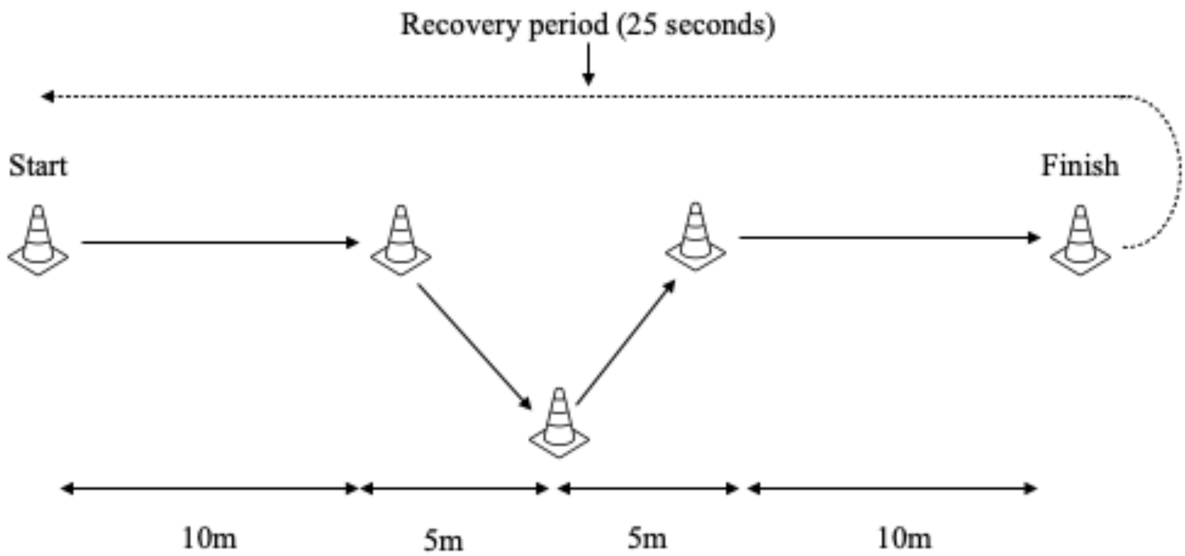

FIGURE 7. Schematic presentation of the RSA-test (Modified from Bangsbo, 1994).

8.3.3 Countermovement jump

To assess lower limb power, the vertical countermovement jump (CMJ) was used. Participants stood with both feet on a SpinTest^{TM} (Spin Test Oy, Tallinn, Estonia) contact grid with their hands on their hips. Participants were asked to jump as high as possible using a countermovement, keeping their hands on their hips and without bending their knees while in the air. Jump height was determined by the SpinTest^{TM} (Spin Test Oy, Tallinn, Estonia) software.

8.3.4 Linear speed

Linear speed was assessed using SpinTest^{TM} timing gates. Participants were instructed not to sway back-and-forth at the starting line which was placed 0.7m before the first timing gates. Participants were instructed to sprint 30m as fast as possible. Split times were measured at 5m, 10m and 30m.

8.4 Statistical analysis

Results are presented as mean ± standard deviation (SD). Statistical analysis was performed using SPSS 28 (International Business Machines Corporation, New York, USA) and Microsoft Excel 2018 (Microsoft Corporation, Washington, USA). Differences between males and females in the performance tests were tested using the independent samples t-test. Independent samples t-test was also used to test differences in the performance tests between age groups. The relationship between speed, power, RSA and endurance scores were assessed using the Pearson product-moment correlation. The magnitudes of the correlations were considered as trivial (<0.1), small (>0.1–0.3), moderate (>0.3–0.5), large (>0.5–0.7), very large (>0.7–0.9), nearly perfect (>0.9), and perfect (1.0) according to Hopkins et al. (2009). Linear regression analyses were conducted after the Pearson product moment correlation to determine the amount of variance in endurance capacity and RSA explained by sprint speed and/or vertical jump ability. The significance level was set at $p < 0.05$.

9 RESULTS

9.1 Performance testing results

TABLE 2. Descriptive performance test results for males and females (mean ± SD).

	Male (n=81)			Female (n=73)		
	U15	U17	Total	U15	U17	Total
Performance test						
YYIETL2 (m)	1971.1 ± 370.6	2058.3 ± 349.1	2030.3 ± 356.2†	826.1 ± 236.1	924.7 ± 320.5	886.8 ± 293.2
CMJ (cm)	34.0 ± 3.8	35.7 ± 3.8	35.2 ± 3.8†	24.7 ± 2.4	25.5 ± 3.0	25.2 ± 2.8
Speed 5m (s)	1.04 ± 0.05	1.01 ± 0.05*	1.02 ± 0.05†	1.07 ± 0.06	1.08 ± 0.06	1.08 ± 0.06
Speed 10m (s)	1.80 ± 0.07	1.76 ± 0.06*	1.78 ± 0.07†	1.89 ± 0.07	1.89 ± 0.06	1.89 ± 0.06
Speed 30m (s)	4.31 ± 0.14	4.24 ± 0.12*	4.27 ± 0.13†	4.75 ± 0.16	4.74 ± 0.16	4.75 ± 0.16
RSA Avg (s)	6.93 ± 0.23	6.78 ± 0.24*	6.84 ± 0.25†	7.71 ± 0.23	7.66 ± 0.28	7.68 ± 0.26
RSA Total (s)	48.54 ± 1.66	47.51 ± 1.68*	47.84 ± 1.73†	53.99 ± 1.60	53.68 ± 1.95	53.80 ± 1.82

YYIETL2, Yo-Yo intermittent endurance test level 2; CMJ, Countermovement jump; $RSA_{Average}$, Repeated sprint ability test average time; RSA_{Total}, Repeated sprint ability test total time. * Signifies a significant difference between age groups ($p < 0.05$). † Signifies a significant difference between males and females on total score ($p < 0.001$).

There was a significant difference across all the variables between males and females; 5m sprint time ($p < 0.001$), 10m sprint time ($p < 0.001$), 30m sprint time ($p < 0.001$), CMJ height ($p < 0.001$), YYIETL2 ($p < 0.001$), $RSA_{Average}$ ($p < 0.001$) and RSA_{Total} ($p < 0.001$). In males, significant differences were found between the age groups for 5m sprint time ($p = 0.026$), 10m sprint time ($p = 0.045$), 30m sprint time ($p = 0.022$), $RSA_{Average}$ ($p = 0.012$) and RSA_{Total} ($p = 0.012$) but not YYIETL2 ($p = 0.307$) or CMJ height ($p = 0.059$). In females, no significant differences were found in any of the variables between the age groups; YYIETL2

(p = 0.164), CMJ height (p = 0.222), 5m sprint time (p = 0.842), 10m sprint time (p = 0.662), 30m sprint time (p = 0.803), $RSA_{Average}$ (p = 0.466) and RSA_{Total} (p = 0.475).

9.2 Relationship between tests

In males, moderate correlations were observed between the YYIETL2 and the 30m (r = –0.313; P = 0.004), 5m (r = –0.347; P = 0.002), and 10m sprints (r = –0.305; P = 0.006) (Figure 8; Figure 9; Figure 10). No significant correlation was observed between YYIETL2 and CMJ (r = 0.09; P = 0.427). Small correlations, however, not significant, were also observed between RSA_{Total} and CMJ (r = –0.199; P = 0.074) as well as between $RSA_{Average}$ and CMJ (r = –0.197; P = 0.077). Moderate correlations were found between RSA_{Total} and the 30m (r = 0.426; P < 0.001) and 5m (r = 0.360; P < 0.001) (Figure 11; Figure 12) sprint whereas the correlation between RSA_{Total} and 10m sprint was small and not significant (r = 0.140; p = 0.211). Similarly, moderate correlations were observed between $RSA_{Average}$ and the 30m (r = 0.426; P = 0.001), and 5m (r = 0.361; P = 0.001) (Figure 13) sprint but only a small correlation was found between $RSA_{Average}$ and 10m sprint (r = 0.141; P = 0.209).

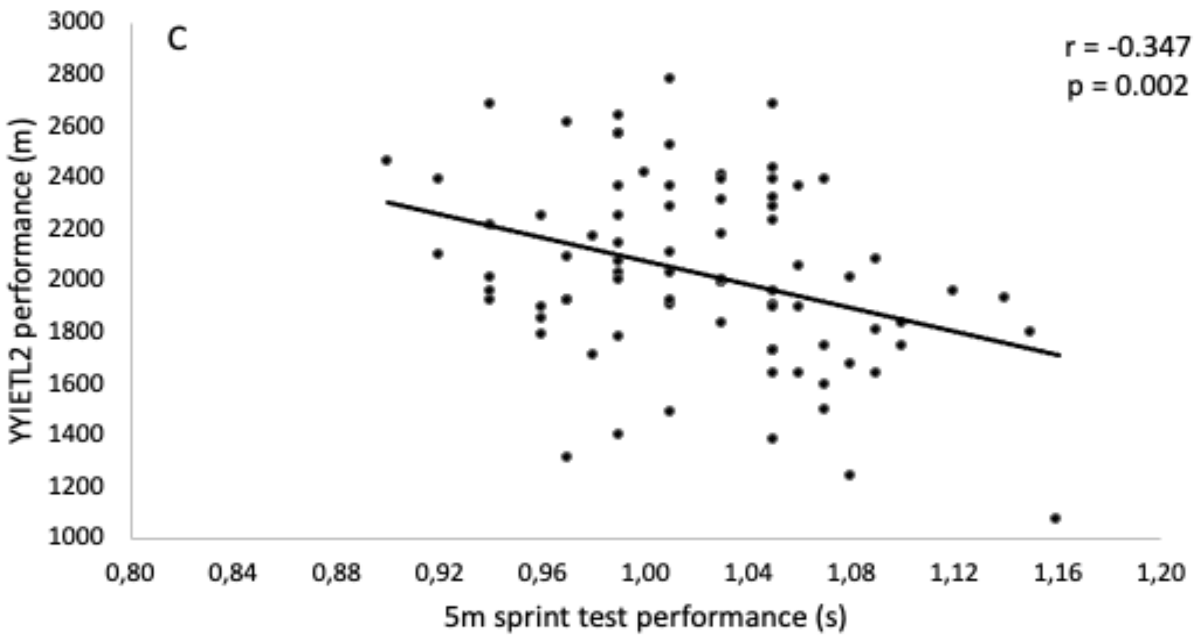

FIGURE 8. Relationship between YYIETL2 and 5m sprint time in male soccer players (n = 81).

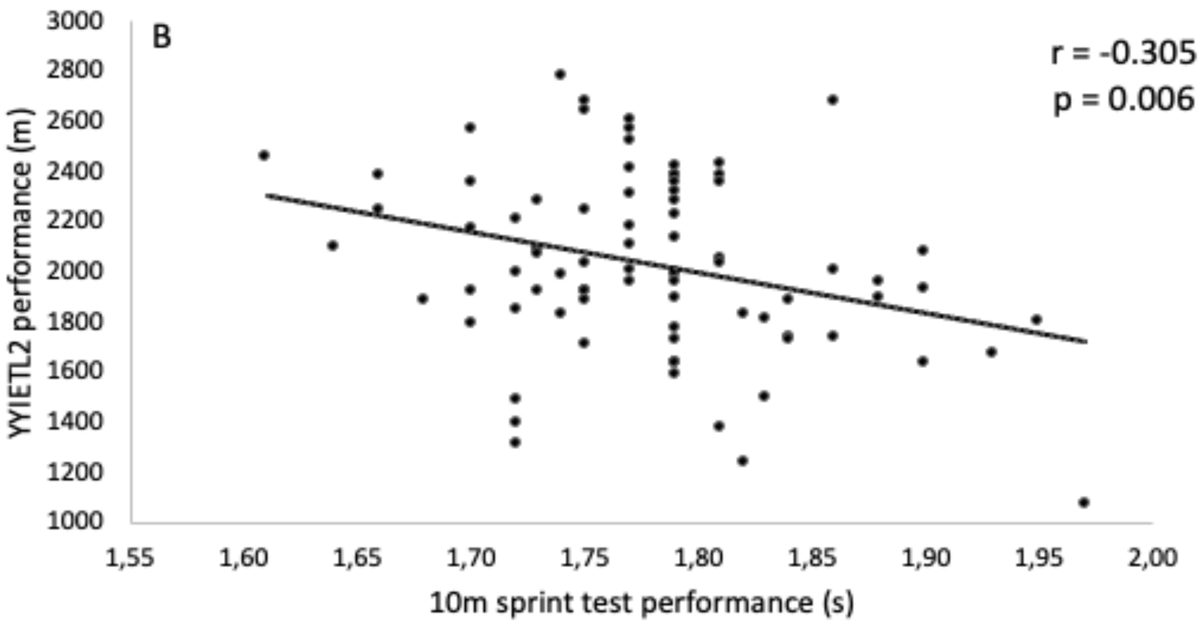

FIGURE 9. Relationship between YYIETL2 and 10m sprint time in male soccer players (n = 81).

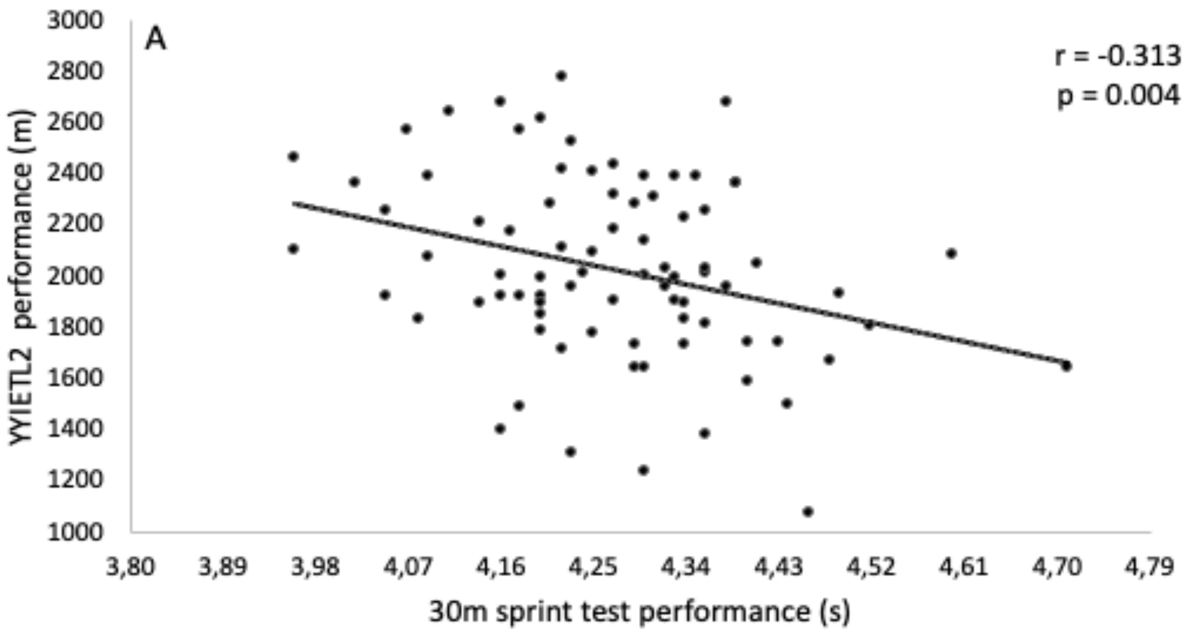

FIGURE 10. Relationship between YYIETL2 and 30m sprint time in male soccer players (n = 81).

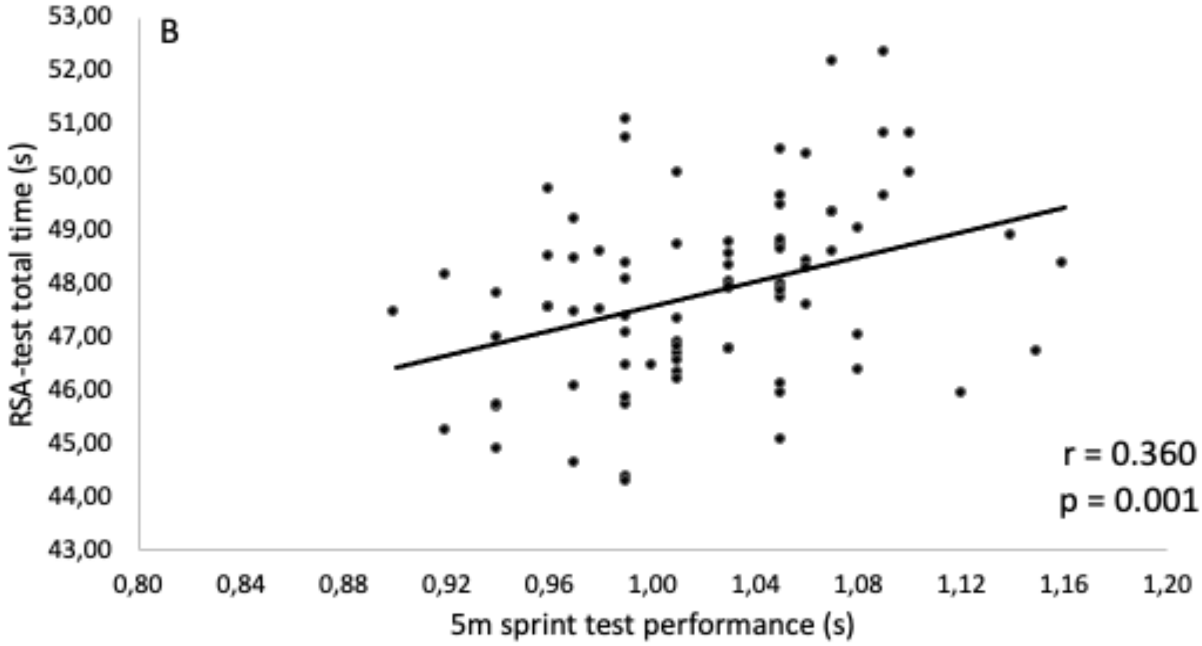

FIGURE 11. Relationship between RSA_{Total} and 5m sprint time in male soccer players (n = 81).

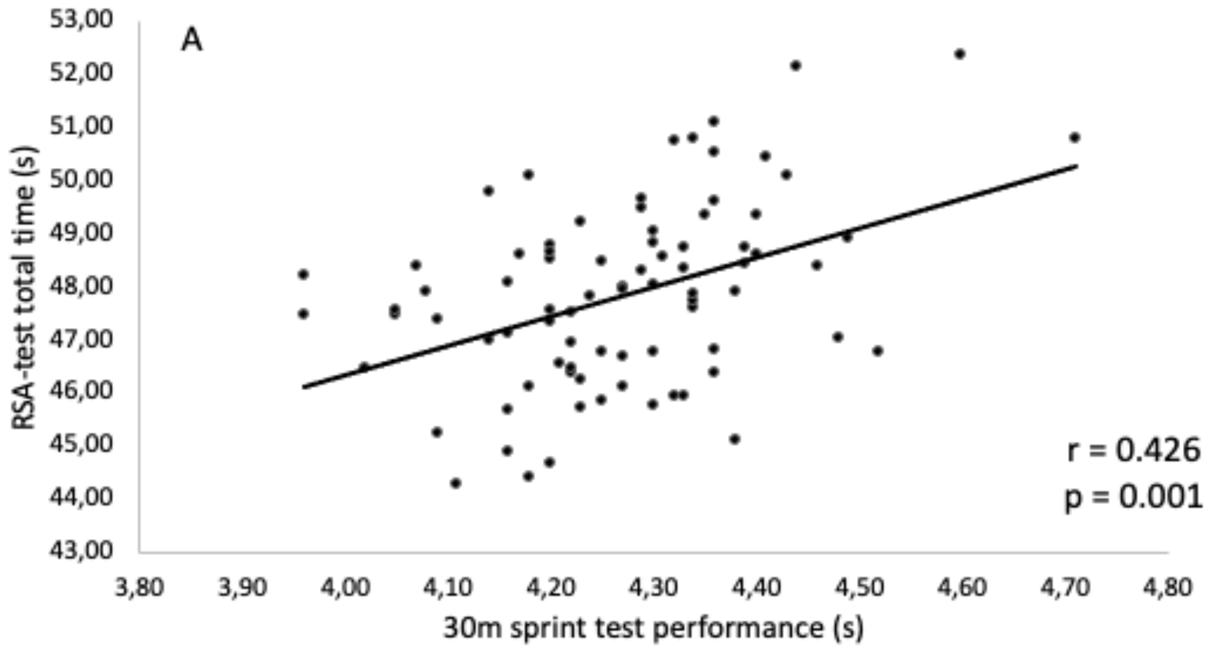

FIGURE 12. Relationship between RSA_{Total} and 30m sprint time in male soccer players (n = 81).

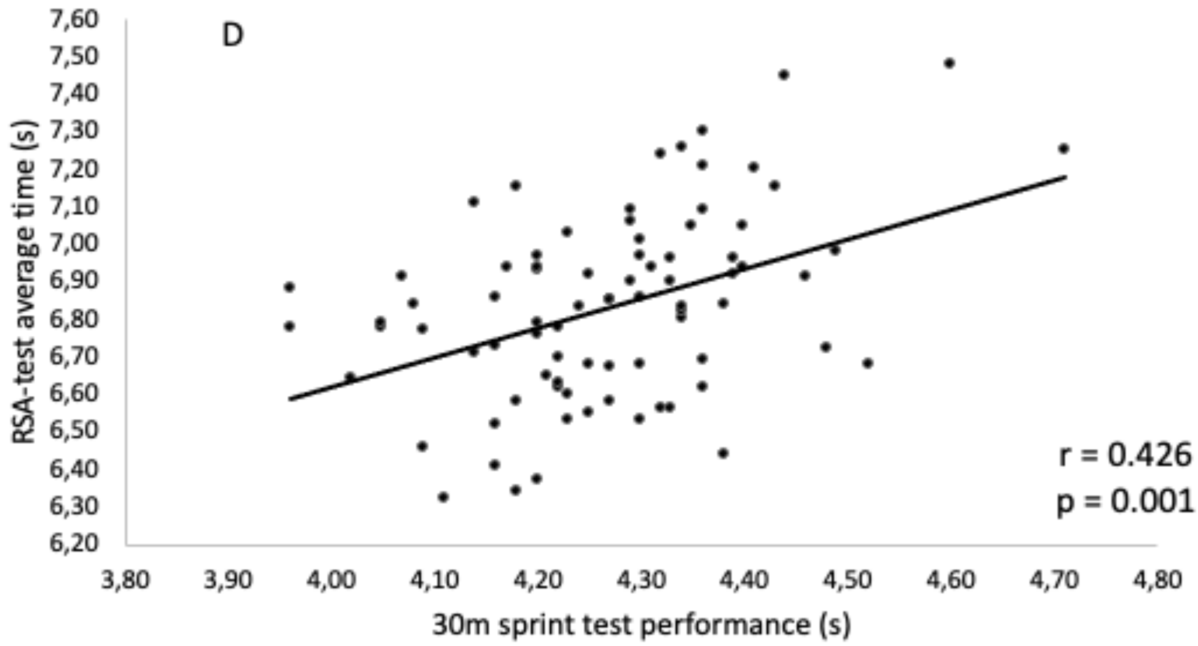

FIGURE 13. Relationship between $RSA_{Average}$ and 30m sprint time in male soccer players (n = 81).

Among females, moderate correlations were observed between the YYIETL2 and the 30m (r = –0.394; P < 0.001), 10m (r = –0.325; P = 0.005), and 5m sprints (r = –0.307; P = 0.008) (Figure 14; Figure 15). A moderate correlation was observed between the YYIETL2 and CMJ (r = 0.328; P = 0.005). Moderate correlations were also observed between RSA_{Total} and CMJ (r = –0.431; P < 0.001) and between $RSA_{Average}$ and CMJ (r = –0.416; P < 0.001). Large correlations were observed between RSA_{Total} and the 10m (r = 0.579; P < 0.001) and 5m (r = 0.501; P < 0.001) sprints with a very large correlation between RSA_{Total} and the 30m sprint (r = 0.719; P < 0.001) (Figure 16). Similarly, large correlations were found between $RSA_{Average}$ and the 10m (r = 0.580; P < 0.001) and 5m (r = 0.502; P < 0.001) sprints with a very large correlation between $RSA_{Average}$ and the 30m sprint (r = 0.705; P < 0.001) (Figure 17).

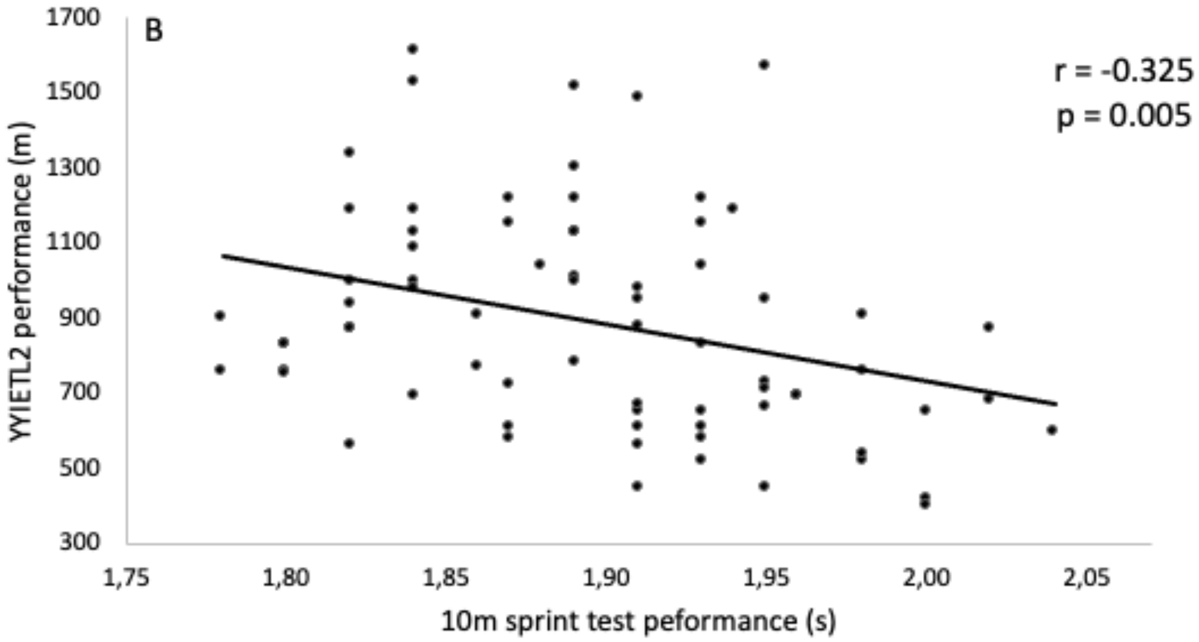

FIGURE 14. Relationship between YYIETL2 and 10m sprint time in female soccer players (n = 73).

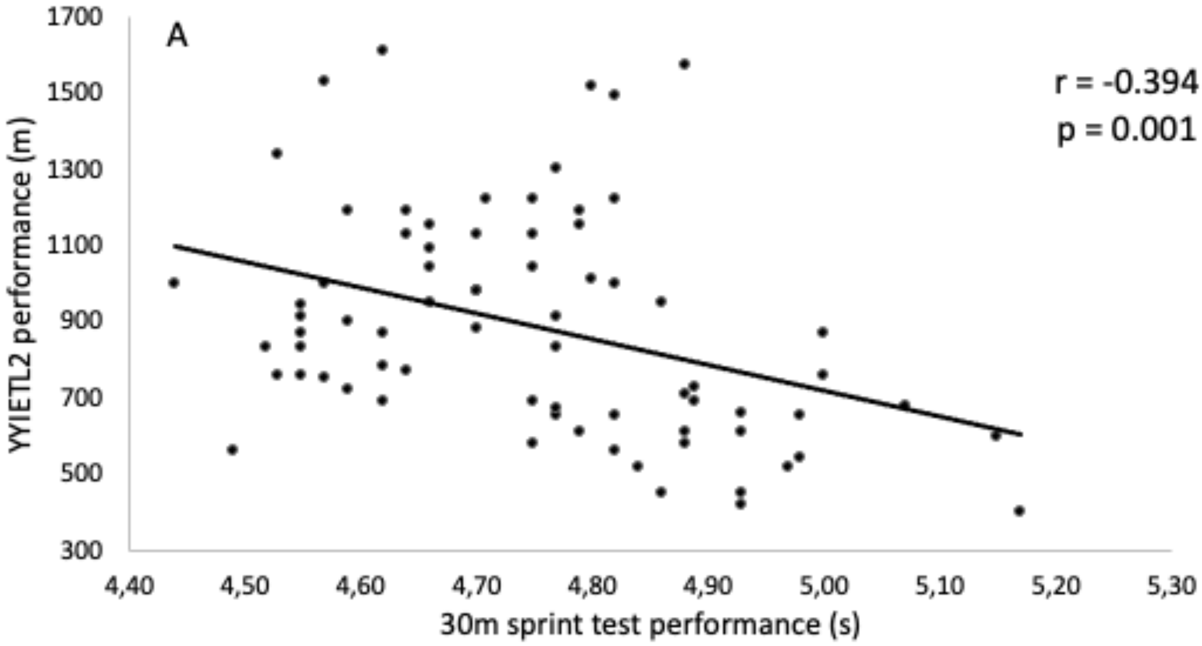

FIGURE 15. Relationship between YYIETL2 and 30m sprint time in female soccer players (n = 73).

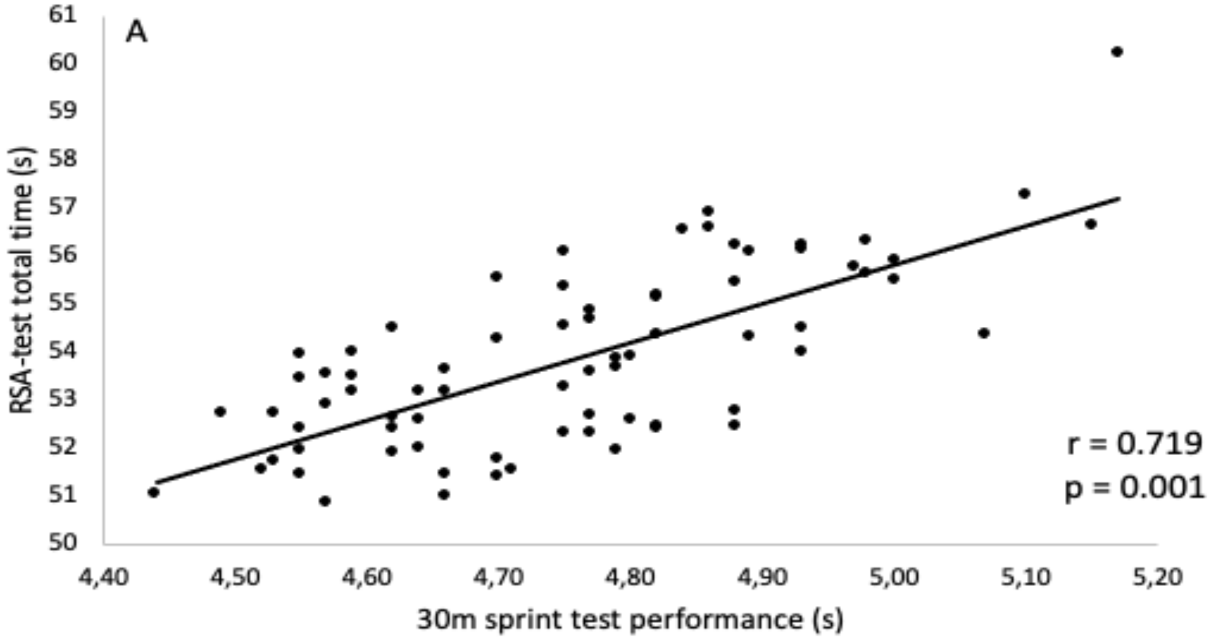

FIGURE 16. Relationship between RSA_{Total} and 30m sprint time and in female soccer players (n = 73).

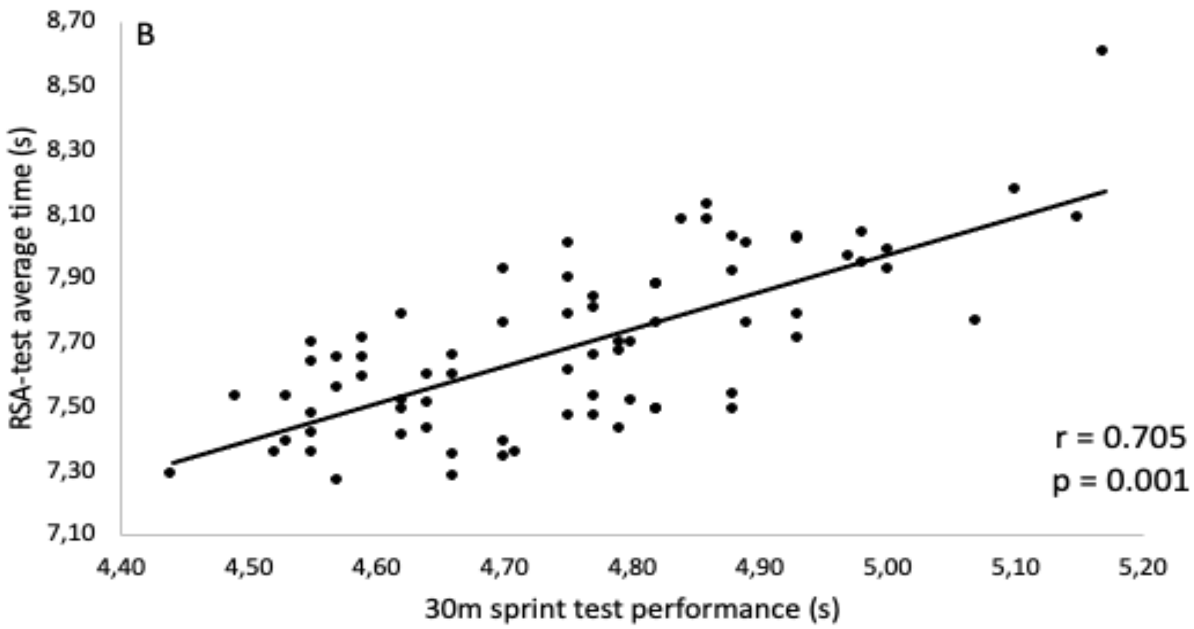

FIGURE 17. Relationship between $RSA_{Average}$ and 30m sprint time in female soccer players (n = 73).

9.3 Linear regression

In males, the linear regression analysis showed that the 30m sprint explained 9.8 % of the variance in the YYIETL2 (R^2 = 0.098, p = 0.004), whereas 10m sprint explained 9.3 % of the variance (R^2 = 0.093, p = 0.006) and 5m sprint explained 12 % of the variance (R^2 = 0.12, p = 0.002). Conversely, CMJ did not significantly explain any of the variance in YYIETL2 performance (R^2 = 0.008, p = 0.427). For $RSA_{average}$, the 30m sprint explained 18.2 % of the variance (R^2 = 0.182, p = 0.001), whereas 10m sprint explained 2 % of the variance, which was not significant (R^2 = 0.020, p = 0.209). 5m sprint explained 13.1 % of the variance (R^2 = 0.131, p = 0.001) in $RSA_{average}$. CMJ explained 3.9 % of the variance in $RSA_{average,}$ although it was not significant (R^2 = 0.039, p = 0.077). For RSA_{total}, 30m sprint explained 18.2 % of the variance (R^2 = 0.182, p = 0.001), 10m explained 2 % of the variance but was not significant (R^2 = 0.020, p = 0.211) and 5m explained 13 % of the variance (R^2 = 0.130, p = 0.001). CMJ explained 4 % of the variance in the $RSA_{total\ time}$ but was not significant (R^2 = 0.040, p = 0.074).

In females, the linear regression analysis showed that the 30m sprint explained 13.7 % of the variance in the YYIETL2 (R^2 = 0.137, p = 0.001), whereas 10m sprint explained 10.6 % of the variance (R^2 = 0.106, p = 0.005) and 5m sprint explained 9.4 % of the variance (R^2 = 0.094, p = 0.008). The CMJ explained 10.8 % of the variance in the YYIETL2 (R^2 = 0.108, p = 0.005). For $RSA_{average}$, the 30m sprint explained 49.7 % of the variance (R^2 = 0.497, p = 0.001), whereas 10m sprint explained 33.7 % of the variance (R^2 = 0.337, p = 0.001) and 5m sprint explained 25.2 % of the variance (R^2 = 0.252, p = 0.001). CMJ explained 17.3 % of the variance in the $RSA_{average}$ (R^2 = 0.173, p = 0.001). For RSA_{total}, 30m sprint explained 49.5 % (R^2 = 0.495, p = 0.001), 10m sprint explained 33.5 % of the variance (R^2 = 0.335, p = 0.001) and 5m sprint explained 25.1 % of the variance (R^2 = 0.251, p = 0.001). CMJ explained 17.4 % of the variance in the $RSA_{total\ time}$ (R^2 = 0.174, p = 0.001).

10 DISCUSSION

The main findings of this study were that the speed tests showed moderate correlation with the YYIETL2 test in both male and female players at all split times (5m, 10m and 30m). Interestingly, CMJ showed a significant correlation with the YYIETL2 in females but not males. Also, from the regression analysis, it was shown that the performance variables that predict YYIETL2 performance may differ between young males and females. Indeed, in males, short sprint speed (5m) explained the highest percentage of variance in YYIETL2 performance while in females, longer sprint speed (30m) explained the highest percentage of variance.

The differences between male and female soccer players in soccer-specific field tests have been shown by previous literature (Stølen et al., 2005; Mujika et al., 2009). For example, the Yo-Yo score (total distance) is far greater for male players than female players, also between junior and senior players it can discriminate the experience level in both males and females (Rampinini et al., 2007; Mujika et al., 2009). It has been suggested that this is partly due to the greater lower limb power in male players (Castagna et al., 2006). Also, it has been suggested that in intermittent performance the body composition plays a role in a performance that is predominantly aerobic (Krustrup et al., 2006a). In this study, the body composition was not included in pre-tests, which could have added valuable information in regards to the differences between males and females. The CMJ differences between sexes are in line with previous studies (Helgerud et al., 2001; Mujika et al., 2009). Also, these differences are more significant at the youth level than at the senior level (Mujika et al., 2009). These results show that explosive power should be considered for training in youth female players. The differences in speed performance between male and female soccer players have been partly explained by the differences in lower body power and body composition (Haugen et al., 2014). The body composition plays a more crucial role in post-pubertal players, as it has been indicated that female players tend to struggle in improving their sprint-velocity post-puberty (Haugen et al., 2014). Meanwhile, muscular strength is related to the muscle cross-sectional area, it is important to highlight these differences between male and female players in strength-related tests (Stølen et al., 2005).

Helgerud et al (2002) reported in their study with female players that in relative terms to body mass the CMJ height was 76 % of their male counterparts, which shows that the strength differences are heavily influenced by the size differences. Also, it has been suggested that the differences between sexes in capacity to move oneself for example in sprints or jumps is partly explained by the differences of the type of strength training is focused on (i.e maximal, velocity-based) or the priority of strength training compared to other training modalities (Stølen et al., 2005).

This study was one of the first to examine if speed and power tests could predict endurance performance in both male and female youth soccer players. Additionally, this study examined the correlations between the most used field tests for soccer performance. The YYIETL2 test has not received as much attention in the literature as the other variations of the Yo-Yo tests (Krustrup & Bangsbo 2001; Castagna et al., 2009; Bradley et al., 2011; Bradley et al., 2014). This has been partly due to the nature of the test protocol as the resting period and the speed increments are different (Castagna et al., 2009). However, the YYIETL2 is a valid method for assessing soccer-specific endurance capacity (Krustrup & Bangsbo 2001; Castagna et al., 2009). The YYIETL2 has also been shown to correlate highly with running performance during a competitive match in both male and female players (Bradley et al., 2011; Bradley et al., 2014). It has been shown that female players possess lower physical capacity than male players in various anaerobic and aerobic fitness tests (Stølen et al., 2005; Mujika et al., 2009). In this study, the YYIETL2 showed moderate correlations with all sprints (5m, 10m and 30m) in both males and females. While this finding is somewhat consistent with previous research, YYIETL2 performance has typically been compared to the total high-speed distance covered during a match (Castagna et al., 2009; Castagna et al., 2010) or to the number of high-intensity actions during a match (Castagna et al., 2009; Castagna et al., 2010) rather than absolute sprint speed. This makes it difficult to compare results across studies.

Surprisingly, the relationship between lower body power (CMJ) and soccer-specific endurance capacity (YYIETL2) was moderate in females but trivial in males. These findings partly support the hypothesis that there is no significant relationship between lower limb power and soccer-specific endurance capacity in this study. This was also seen in the regression analysis as the CMJ score predicted a higher percentage of the variance in

YYIETL2 in females than in males. Castagna et al (2006) found no significant correlation between CMJ height and YYIETL2 in adult amateur players. Similar findings were shown by Shalfawi et al (2014) who showed that CMJ height did not significantly correlate with Multi-Stage Fitness Test (MSFT) in young female soccer players. The findings from Shalfawi et al (2014) go against the findings from this study as there was a significant correlation between the YYIETL2 and CMJ. It should be noted, however, that the shuttle run test used in their study had a different protocol, specifically, as there is no resting period, and the starting speed is lower than in the Yo-Yo intermittent tests which makes comparing results difficult. This might be partly explained by the active recovery period in the YYIETL2. Castagna et al (2010) however, suggested in their study that the MSFT and Yo-Yo Intermittent Recovery Test Level 1 (YYIRTL1) could be used interchangeably for soccer-specific endurance testing for young male players. However, since sprint speed and CMJ performance only explained small percentages of the variance in YYIETL2 performance, YYIETL2 performance is likely related to several other factors. This indicates that the endurance capacity of soccer players should be trained independently from speed and power.

In this study, players performed the modified RSA test, which had multiple change of direction (COD) in the testing protocol. The finding of a significant relationship between RSA and maximal sprinting speed is supported in the literature (Rampinini et al., 2007; Shalfawi et al., 2014). Bishop et al (2011) have highlighted that linear sprinting performance is one of the key components of RSA. This is supported by this study as the predictability of RSA by sprint speed was found to be very high, at least in female players. It has also been suggested that in order to enhance RSA, linear sprinting training over short distances might offer better improvements than repeated sprint training (Bishop et al., 2011). This conclusion requires further research, however, to be substantiated. It should also be noted that the RSA-protocol used in this study contained COD movements, which is often not used to this extent in traditional RSA-protocols (Krustrup et al., 2006b; Reilly et al., 2000; Rampinini et al., 2007). As traditional RSA protocols only have one COD, which is performed at 180 degrees (Krustrup et al., 2006b; Rampinini et al., 2007). Currently, there is no gold standard RSA-protocol and thus, a lack of consensus exists as to which RSA-protocol should be used (Glaister, 2008).

In the study by Shalfawi et al (2014) they reported lower times for the RSATotal than in the current study (35.25 ± 1.4 m). In their study, female players were aged age 19 ± 4 years compared to (U15 (n=28), 15.4 ± 0.3, U17 (n=46) 16.9 ± 0.6) in this study. This could partially explain the differing results. Another potential explanation for the difference in RSATotal between this study and Shalfawi et al (2014) could be that their RSA protocol used only linear sprinting (7 x 30m) without any CODs. Including CODs likely affects RSA performance as participants must deaccelerate before turning and then reaccelerate through the finish line. Also, the resting time in their study was 30s total compared to 25s in this study. This difference in recovery time could potentially affect the restoration of phosphocreatine stores and lactate removal depending on the aerobic capacity of the player (Bishop et al., 2011; Stølen et al., 2005; Baldi et al., 2017). In the study by Rampinini et al (2007) they suggested that the physiological requirements for good RSA might be similar to the physiological requirements for good performance in soccer. The finding of only a moderate correlation between sprint speed and RSAAverage in this study challenges this assumption. Indeed, since during a match players must perform for longer periods (ie., 90min), high-intensity actions (sprints) are inevitably separated by periods of low-intensity actions (i.e., jogging and walking). Since RSA tests do not require these low-intensity actions, they may not be a valid measure of soccer-specific performance. This makes it difficult to draw any conclusions based on the studies showing direct validity to match performance and tests (Bishop et al., 2011).

Lastly, both RSA variables showed a moderate correlation to CMJ in females and a small correlation in males. However, the correlation was significant only in females. Against the findings of this study, Baldi et al (2017) showed that in collegiate male soccer players, CMJ performance showed a large, significant correlation with RSA. However, it should be noted that they recorded much higher scores for CMJ (46.1 ± 4.7) compared to this study. The correlations between RSA and CMJ could be explained by the better ability of their players to use stored elastic energy in the performance of stretch-shortening cycle movements (Baldi et al., 2017). Therefore, the poor correlation of RSA and CMJ in males in this study might be partly explained by the poor usage of stored elastic energy during a repeated sprint performance.

10.1 Strength and limitations

This study was one of the first to investigate relationships between popular field tests in soccer performance. Often, research has focused on direct validity between tests and soccer match performance (Castagna et al., 2007; Rampinini et al., 2007). In this study, the focus was to investigate the relationship between speed and power on endurance via soccer-related field tests. This study also highlights the differences between male and female players and how the relationships differ between the sexes in soccer-specific field tests. However, more research is needed to clarify the causes of these differences.

The current study also possesses some limitations that should be considered when compared to other studies. One of the main problems of correlation studies has been identified as the value of the correlation is sensitive to sample homogeneity, which may affect the results (Hopkins, 2000). In this study, the usage of the RSA-test which uses a COD in the middle of the sprint could affect the results because higher times were recorded compared to other studies (Shalfawi et al., 2014; Baldi et al., 2017). Similarly, the YYIETL2 score was lower for females than reported for young females by Bradley et al (2014). As mentioned earlier there is not a gold standard protocol for the RSA-test, however, it has been suggested that the construct validity of RSA-tests would be in high regard because of the match-related physical performance (Rampinini et al., 2009). A methodological limitation of the study could be that the data presented in this study did not show how many tries participants had in each test (i.e., linear sprinting). From a methodological point of view in most tests' participants have multiple tries in each test because there can be slight changes in scores and then from each participant, the best time can be included in the statistical analysis. Also, the data chosen for this study was a cross-section of a larger data population and, therefore, might introduce a bias. The bias might be that the data population does not represent the overall population and in the case of this study, the players might have different physical attributes, even though they are from the same competitive level.

11 CONCLUSION

This retrospective analysis showed that sprint speed was moderately related to soccer-specific endurance performance in both female and male youth soccer players. This is in line with previous research where it has been shown that endurance performance is significantly correlated to high intensity running and the number of high-intensity actions performed during a match (Bradley et al., 2011; Bradley et al., 2014). This study also shows that lower limb power (CMJ performance) is only moderately related to soccer-specific endurance capacity in female players and is not related to male players.

In this study, males recorded significantly better scores than females in all test variables. This finding is in line with the previous research showing that female players possess lower physical capacity than male players in various anaerobic and aerobic fitness tests (Stølen et al., 2005; Mujika et al., 2009). However, the performance testing results of this study were lower than those reported elsewhere in similar populations (Shalfawi et al., 2014; Baldi et al., 2017; Bradley et al., 2014). This could have affected the analysis of this study and caution should be used when compared to other studies. Also, close attention should be paid to the testing procedures when comparing results across studies as the protocols of certain tests may vary. It is important to note that these differences between male and female players are especially evident at the youth level (Mujika et al., 2009). Also, it has been suggested that with young female players it is an important aspect that the coaches should include specific explosive power training in their training regime when working with young female players.

Due to the limitations of this study, more research is needed to determine the cause of these relationships between test performance in both male and female soccer players. Although it seems that sprint speed and lower body power are related to endurance performance in soccer, the small to moderate correlations established in this study indicate that endurance capacity should be trained independently. The relationship between sprint speed, lower body power, and soccer-specific endurance capacity was much stronger in females than in males. This should be taken into consideration when planning training for female soccer players. In female players, it is important to focus on velocity-based strength training as it has been shown that in post-puberty female players it is harder to improve their sprint velocity (Haugen et al., 2014). However, more research is needed to identify different training strategies for males and females and to determine the causal relationship between soccer performance-related field tests. Lastly, efforts should be made to come to a consensus regarding which testing protocols should be used to properly evaluate soccer-specific performance (Rampinini et al., 2007).

11.1 Practical applications

This study demonstrated that there are differences between males and females in terms of how speed and power relate to soccer-specific endurance performance. However, the moderate to small correlations do not allow for predictable arguments. These results may be indicators for coaches and training staff to consider when planning training. From a practical point of view, it seems that these soccer performance-related tests are independent indicators of soccer performance. Therefore, it may be important to assess performance from a multitude of performance-related tests, rather than choosing one or two. This is especially important in soccer where the complexity and multifactorial nature of the match performance create challenges for performance-related testing. Nonetheless, this study showed that RSA and sprint speed showed large correlations in female players. This information could be used when attempting to enhance RSA in this population by focusing on sprint training in female players. At the youth level, it is important to take into consideration that these players are not miniature adults and when planning different training modalities throughout the season, it is important to plan progression carefully to minimize the risk for overtraining and overreaching. However, coaching staff should realize that there are multiple ways of enhancing RSA (i.e., linear sprinting training, small-sided games and strength training) not limit themselves to just one training modality.

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